Science, Service, Stewardship

Summary of Selected Information on the effects of fine sediment on anadromous salmonids.

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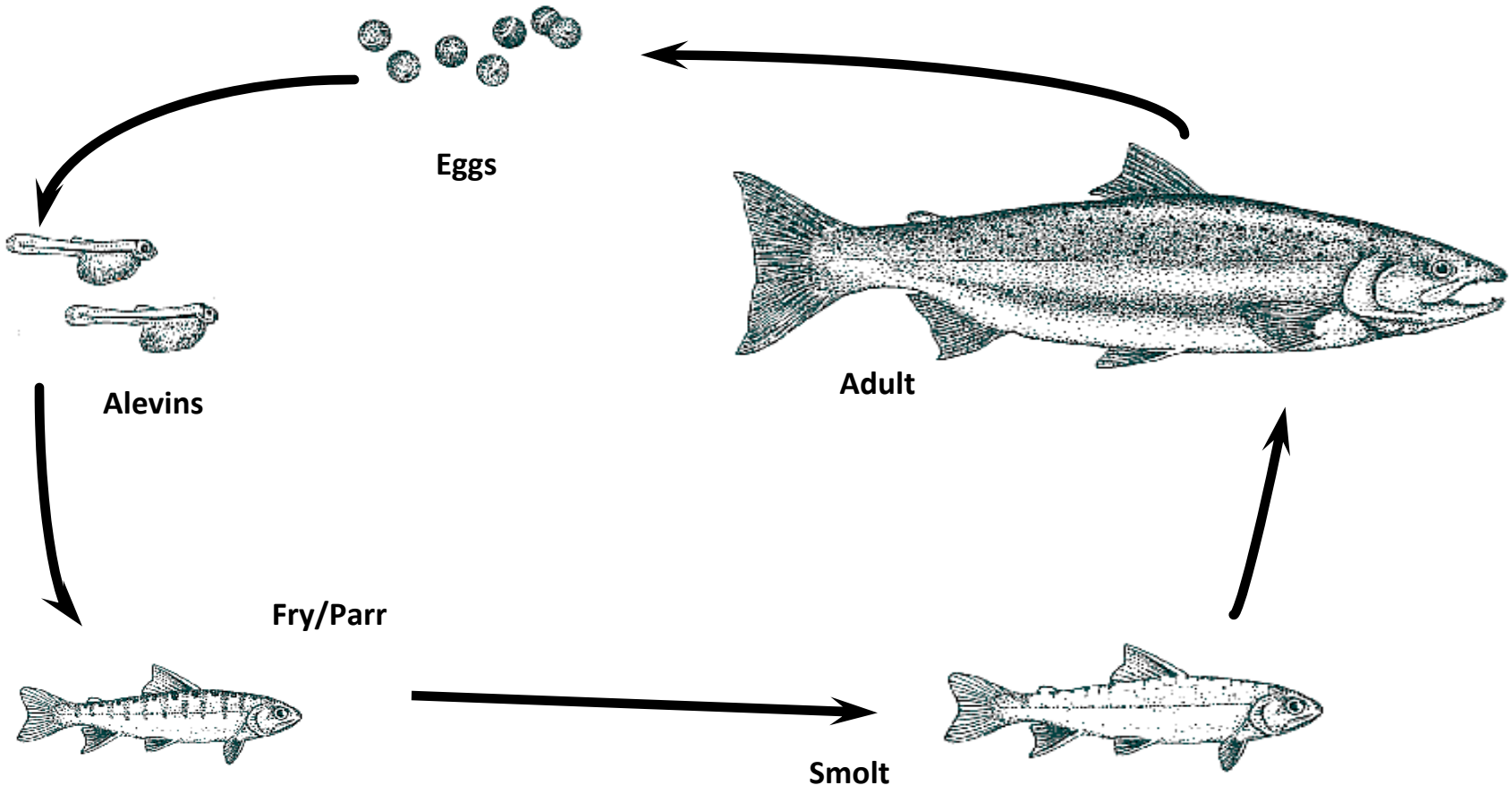
Salmonid Life Cycle



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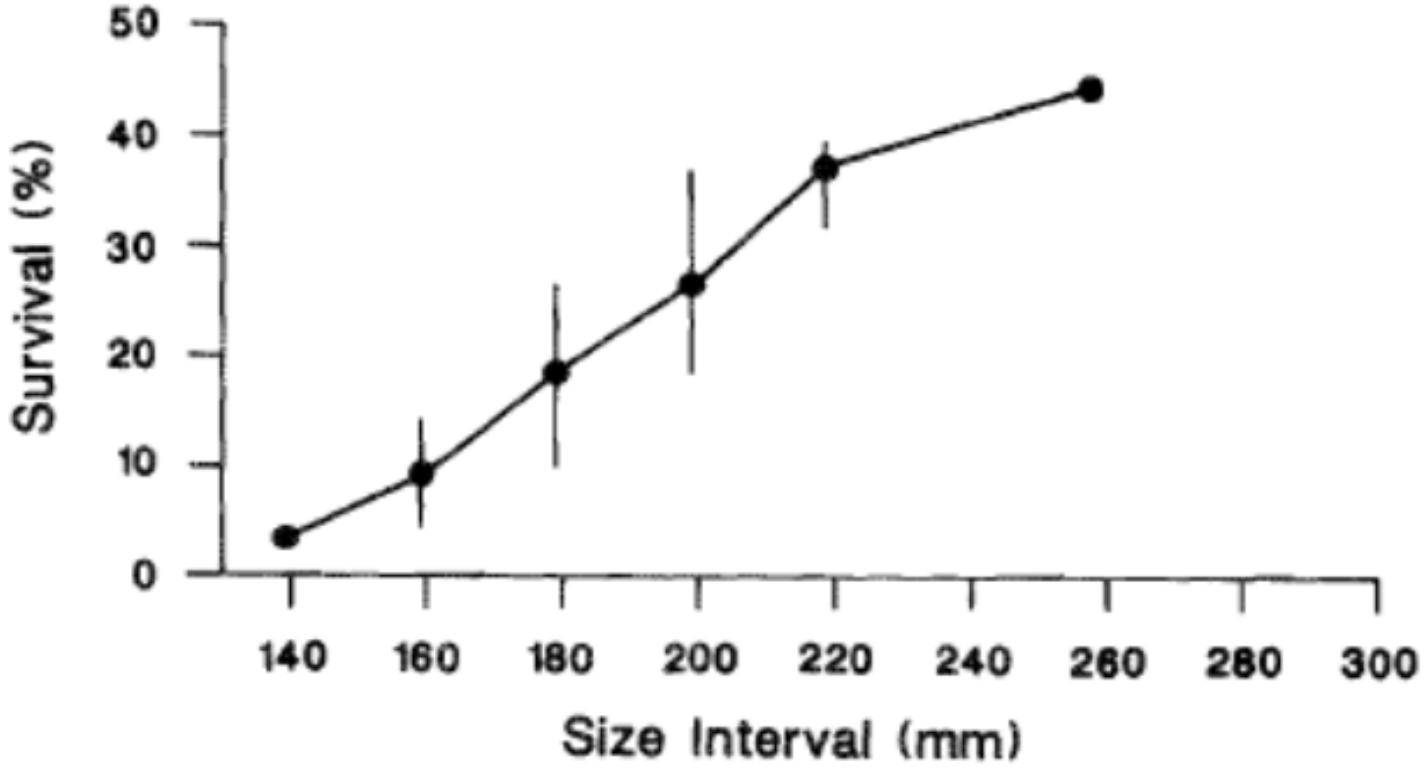
Ward et. al 1989



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Secret to Success

$$I - M - E = G$$

I = ingested food energy

M = metabolism

G = growth

E = energy excreted

(modified from Moyle and Cech 2004)

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Fine Sediment

- Particle sizes analyzed in the literature are generally grain sizes that are <2mm.
- Particle sizes in this range may be periodically transported as suspended load, bed load or deposited channel or on the floodplain.
- All three of these outcomes may have important consequences for stream biota

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Suspended Load vs. Bedload

Suspended Load

•The load whose weight is supported and carried by the column of water within the interstices of the bed grains.

Bed Load

•The moving grain load whose immersed weight is carried by intermittent contact with the immobile bed.

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Effects of Fine Sediment on Salmonids

- Waters (1995) identified 3 relevant categories:
  - Direct effect of suspended load
  - Effects of salmonid reproduction success in redds (i.e. egg to fry survival).
  - Effects of deposited sediment on fry and juvenile salmonid habitat.

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Effects of Suspended Load

- Stress index described by Newcombe and MacDonald (1991) is a function of the concentration of suspended sediment and duration of exposure.

- Shaw and Richardson (2001) tested the direct and indirect effects of the duration of exposure on rainbow trout.

- Lake and Hitch (1999) tested the acute effects of suspended sediment on juvenile coho salmon.

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Newcombe and MacDonald 1991

- Literature review of 70 sources.
- Developed a stress index based on sediment concentration and duration of exposure.

TABLE 1.—Ranking of effects of suspended sediments on fish and aquatic life.

Rank	Description of effect
14	>80 to 100% mortality
13	>60 to 80% mortality
12	>40 to 60% mortality, severe habitat degradation
11	>20 to 40% mortality
10	0 to 20% mortality
9	Reduction in growth rates
8	Physiological stress and histological changes
7	Moderate habitat degradation
6	Poor condition of organism
5	Impaired homing
4	Reduction in feeding rates
3	Avoidance response, abandonment of cover
2	Alarm reaction, avoidance reaction
1	Increased coughing rate

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Newcombe and MacDonald 1991

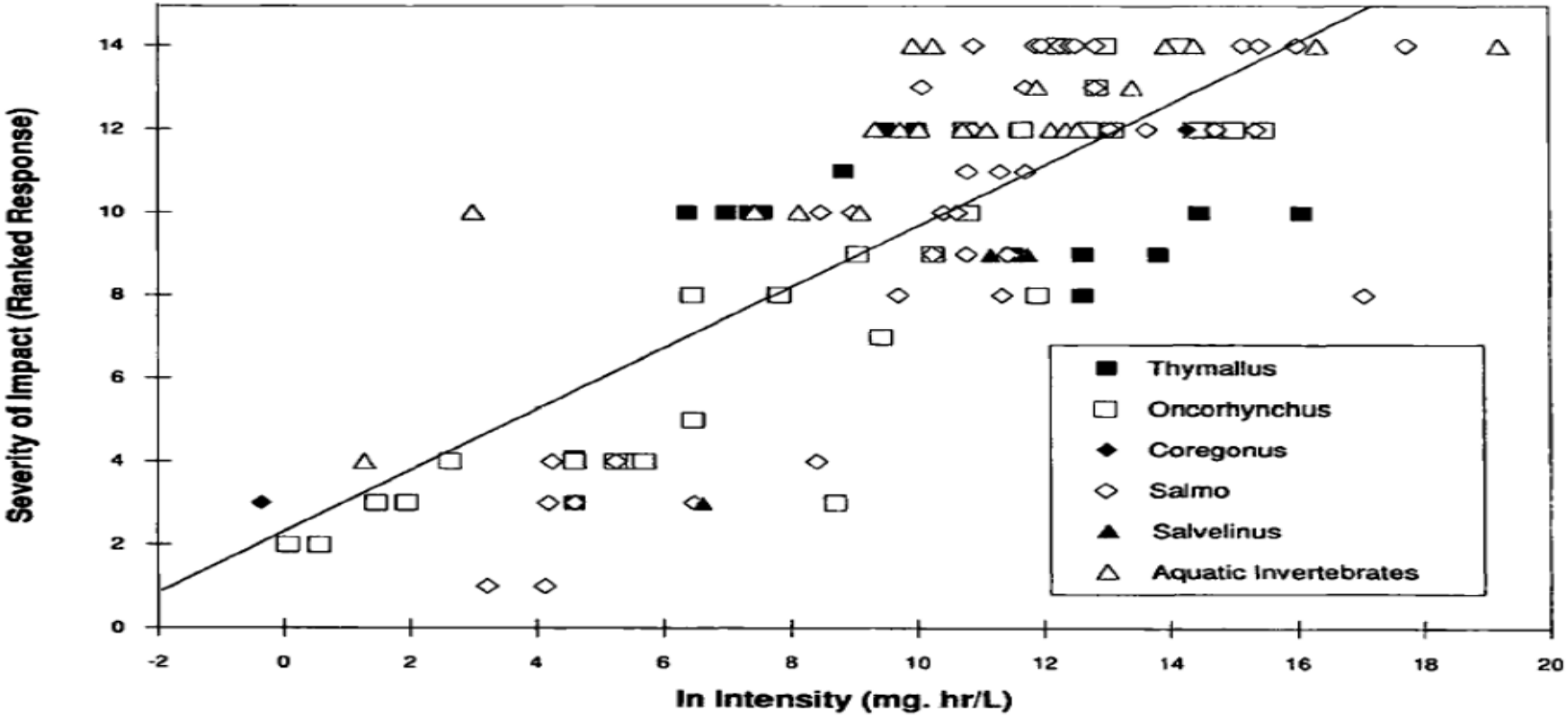

FIGURE 2.—Relationship between $\log_e$ (ln) of suspended sediment intensity and severity of effects on salmonid fishes and aquatic invertebrates. Severity of effect = 0.738 $\log_e$ intensity + 2.179; $r^2 = 0.638$, $N = 120$. Intensity is concentration (mg/L) times duration of exposure (h).

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Shaw and Richardson 2001

- Field laboratory experiment testing acute effects of exposure duration to constant concentration of suspended sediment on RBT.
- 0-6 hour pulses released every 2nd day for 19 days.

Table 1. Fine sediment treatments applied to experimental channels.

Pulse duration (h)	No. sediment pulses	Mean sediment concentration ($mg \cdot L^{-1}$)	Standard error	Number of replicate channels	Dose ($mg \cdot L^{-1} \cdot h^{-1}$)
0	N/A	N/A	N/A	2	0
0.5	10	695.0	15.8	2	3 475
1.0	10	699.0	14.7	2	6 990
3.0	10	701.5	17.9	2	21 045
4.0	10	704.5	12.1	2	28 180
5.0	10	702.0	13.8	2	35 100
6.0	10	705.0	13.7	2	42 300

Note: Each of the seven treatments was replicated twice giving 14 experimental units. Dose is given as the total administered over the duration of the 19-day experiment and is calculated as the product of concentration and duration (product of pulse length and number of pulses). N/A, not applicable.

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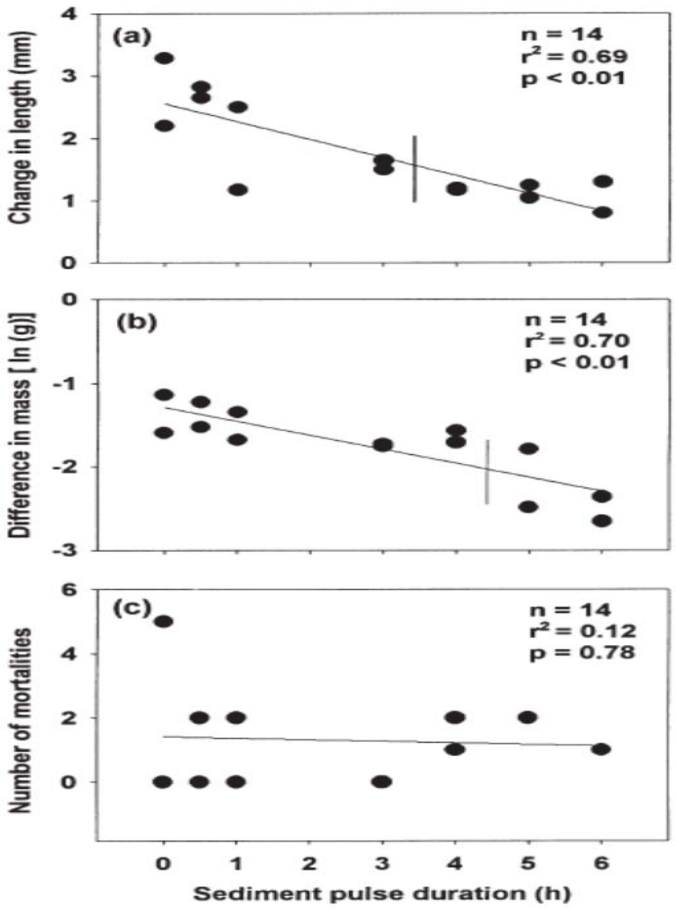
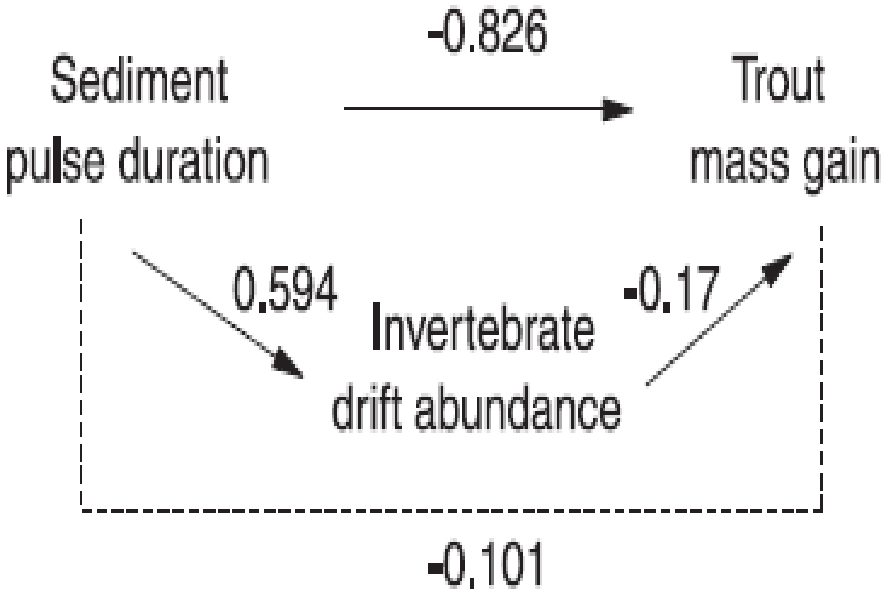
Shaw and Richardson 2001





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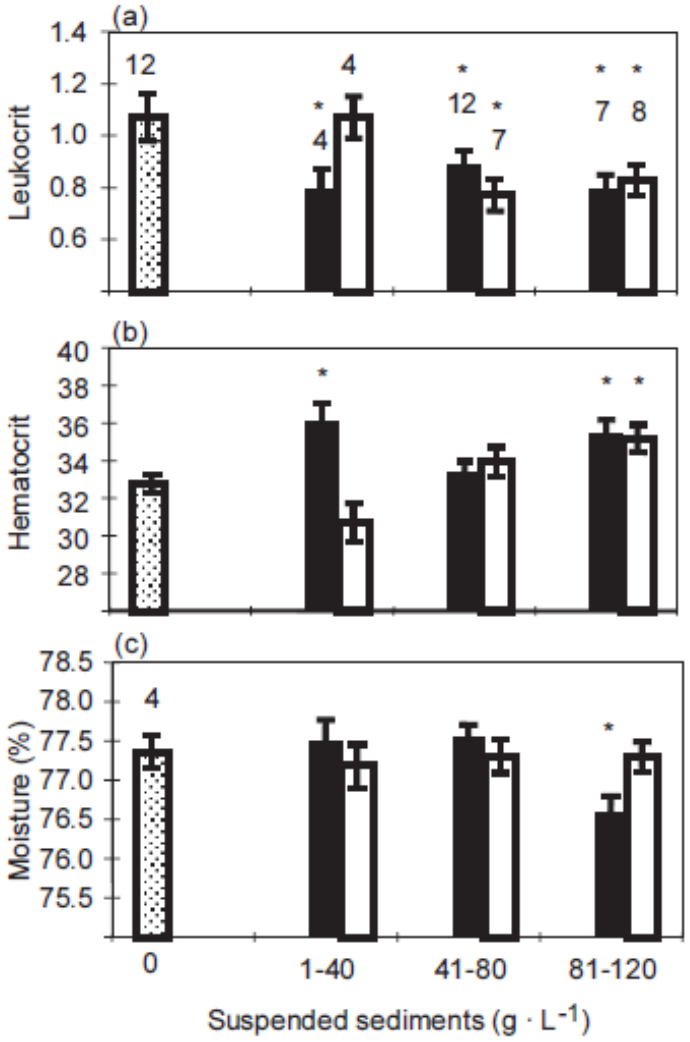
Lake and Hitch (1999)

•Laboratory experiment testing the effects of sediment angularity and concentration as contributors to stress and mortality in salmonids.

•3 treatment categories at a 96 hour duration.

- Low (1–40 g/L)
- Medium (41–80 g/L)
- High (81–120 g/L)



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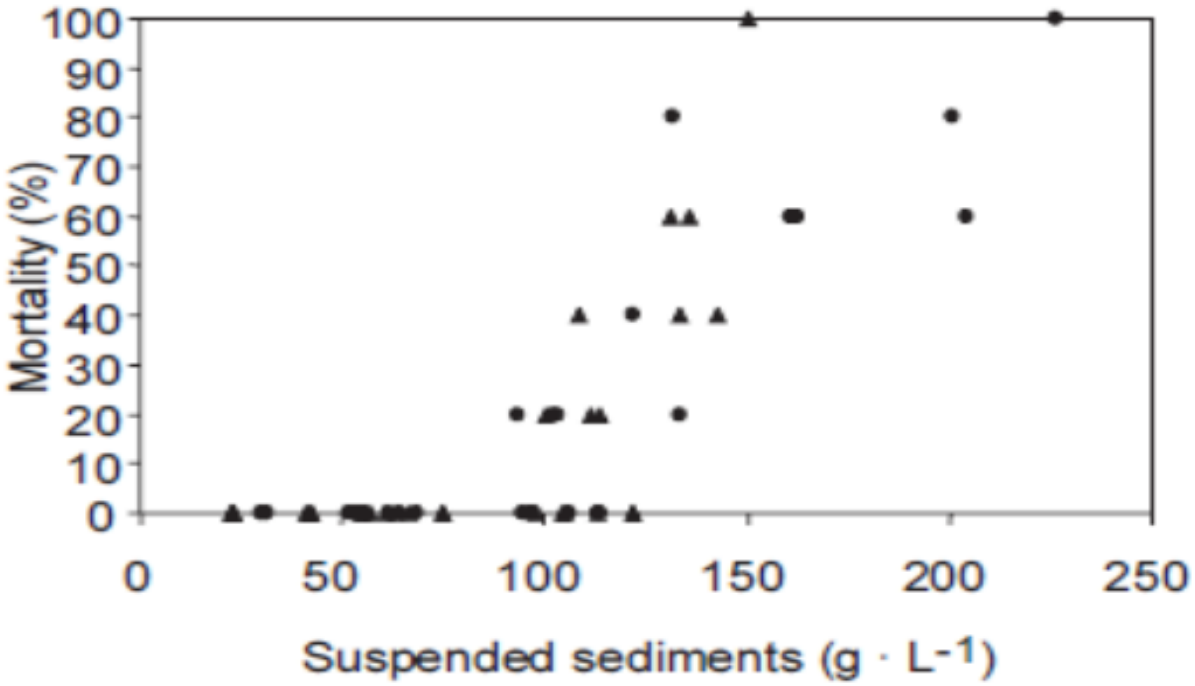
Lake and Hitch (1999)



Regression equation, obtained by pooling round and angular data, was as follows: percent mortality = 0.046 ×concentration – 25.169 ($P < 0.001$, $r2 = 0.621$, $n = 59$)

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NMFS 2005

- Turbidity monitoring on an approved and lawful Timber Conversion Plan (Alder Springs Ranch).
  - NOAA OLE and OGC case #SW0204178
- NTMP, THP, TCP
- Results from independent assessments of physical water quality changes and fish population changes converged and both predicted approximately 20% juvenile steelhead mortality due to suspended sediment from roads and associated land disturbances in conformance with the California Forest Practice Rules.

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Effects of Suspended Load

- Take Home Messages:
  - The effects of suspended load on juvenile salmonids depends on a complex interaction between sediment concentration and duration of exposure.
  - The level of impact to juvenile salmonids resulting from the product of that relationship appears to have a linear correlation.
  - The existing policy for minimizing and avoiding the impacts of suspended sediment is flawed.

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Fine sediment and egg to fry survival (Jenson et al. 2009)

Table 3 Comparison of the change in the odds of survival resulting from a 1% increase in fines

Species	Metric	Change in sediment	Egg stage	Change in odds of survival (%)	95% Confidence interval
Chinook	<0.85 mm	+1%	Green and eyed	−16.9	(−20.4,−13.3)
Coho		+1%	Green and eyed	−18.3	(−23.9,−12.3)
Chum		+1%	Eyed	−13.6	(−18.3,−8.6)
All species		+1%	Green and eyed	−16.9	(−19.1,−14.6)
Chinook	<3.4–4.6 mm	+1%	Green	−6.7	(−9.0,−4.4)
		+1%	Eyed	−14.2	(−18.3,−9.8)
Steelhead		+1%	Green and eyed	−6.0	(−8.3,−3.6)
Coho		+1%	Green and unidentified	−9.2	(−12.4,−5.9)
Chum		+1%		−4.2	(−7.3, −1.0)
All species		+1%	Green and eyed	−7.1	(−8.5,−5.7)
Steelhead	<6.4 mm	10–11%	Green and eyed	−4.1	(−12.0, 4.6)
		30–31%		−10.1	(−21.6, 3.0)
		50–51%		−15.7	(−30.1, 1.5)

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Fine sediment and egg to fry survival

- Take Home Messages:
  - Even small increases in deposited fine sediment substantially increases the likelihood of take of listed salmonids.

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Effects of deposited fine sediment on juvenile salmonid habitat.

- Suttle et al. (2004) experimentally manipulated fine bed sediment in a northern California river and examined responses of juvenile salmonids and the food webs supporting them.

- Harvey et al. (2009) setup a field experiment to measure the influence of deposited fine sediment on the survival and growth of juvenile rainbow trout in northwestern California

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Suttle et al. (2004)

- Field experiment in SF Eel River designed to isolate the effects of deposited fine sediment (i.e.<2mm).
- Steelhead reared in experimented riffles for 46 days.
- 6 experimental embeddedness treatments
  - 100% 80% 60% 40% 20% 0%

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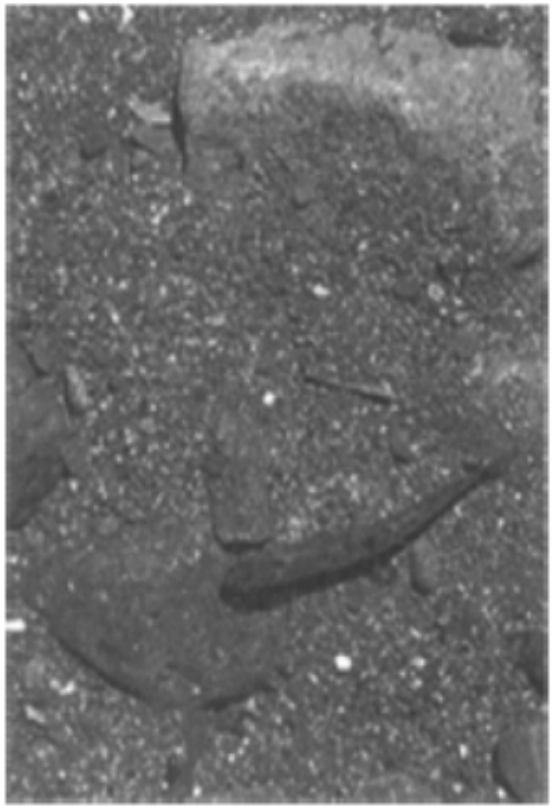
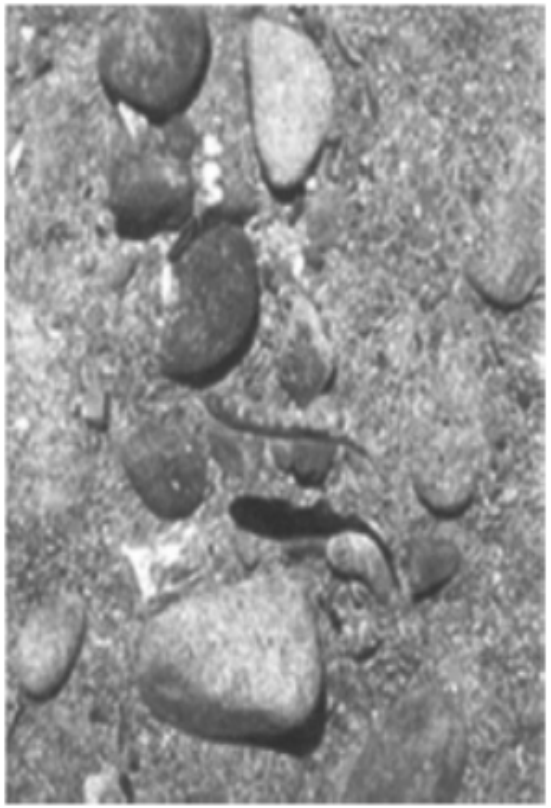
Suttle et al. (2004)





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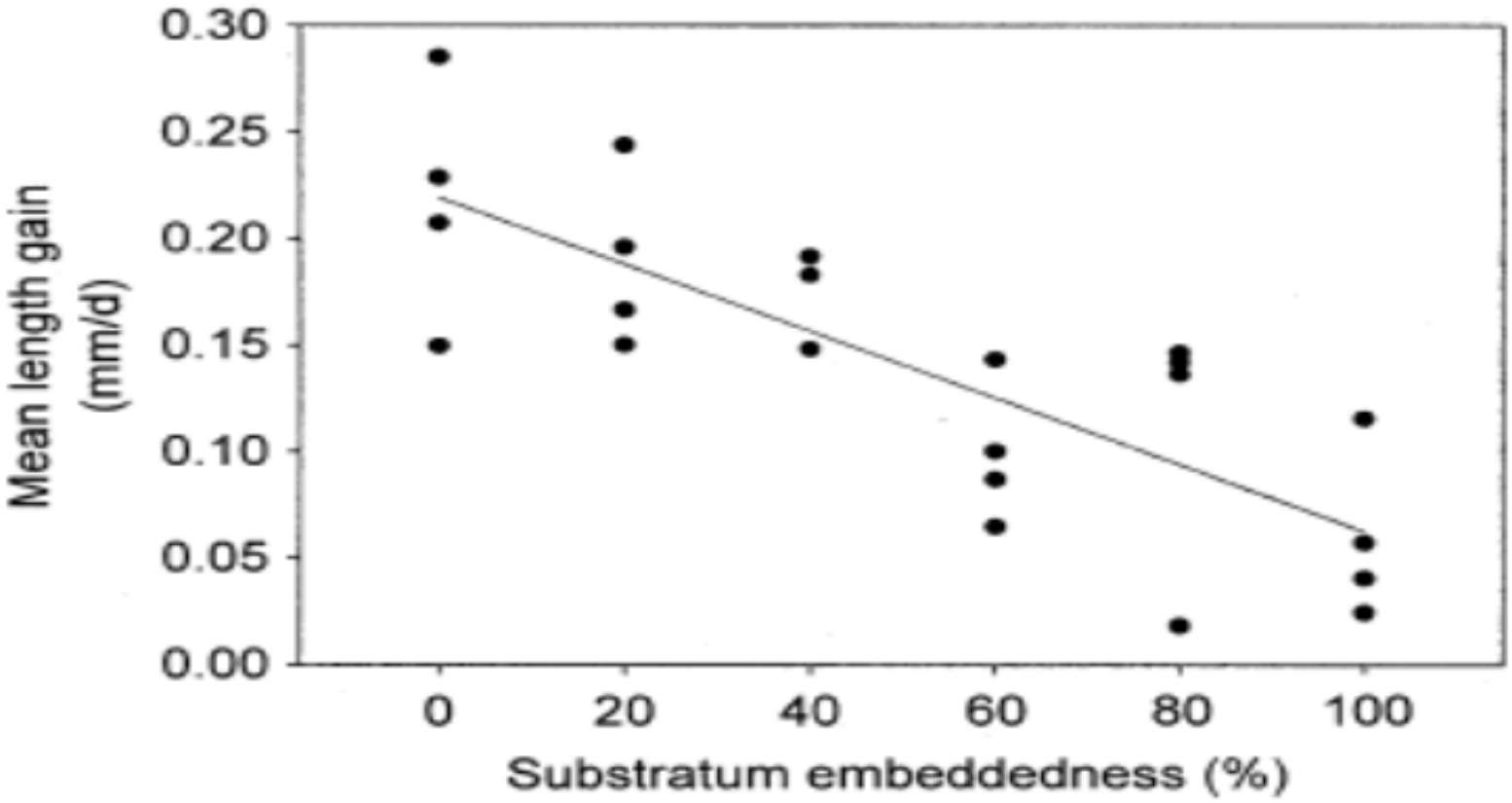
Suttle et al. (2004)



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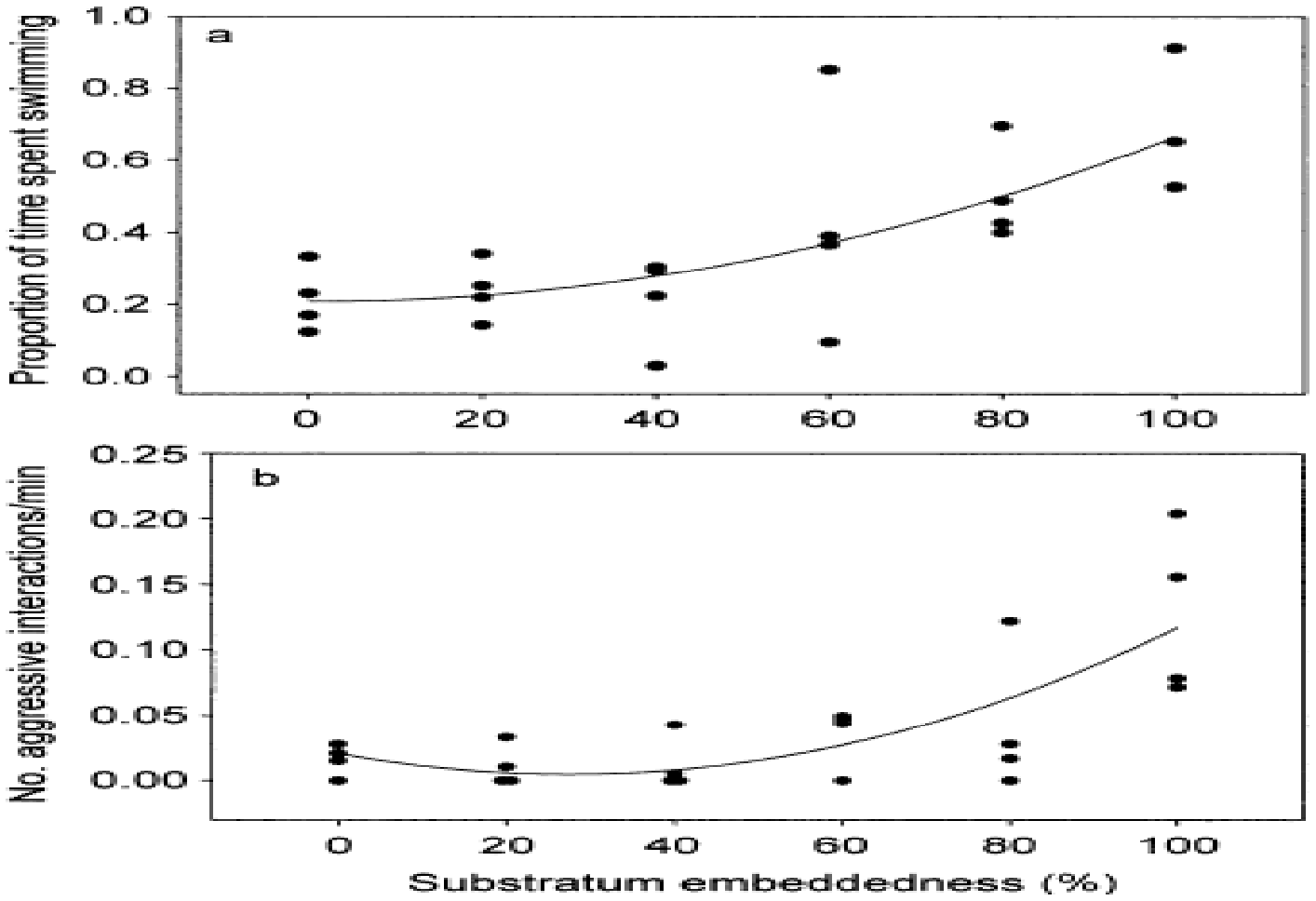
Suttle et al. (2004)



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Harvey et al. (2009)

- Field experiment in Jacoby creek, designed to isolate the effects of deposited fine sediment (i.e. 13-mm-square mesh)

- RBT reared in experimented riffles for 40 days.

- 3 experimental embeddedness treatments
  - Low (about 0%), Background (25-50%), (High 50-100%)

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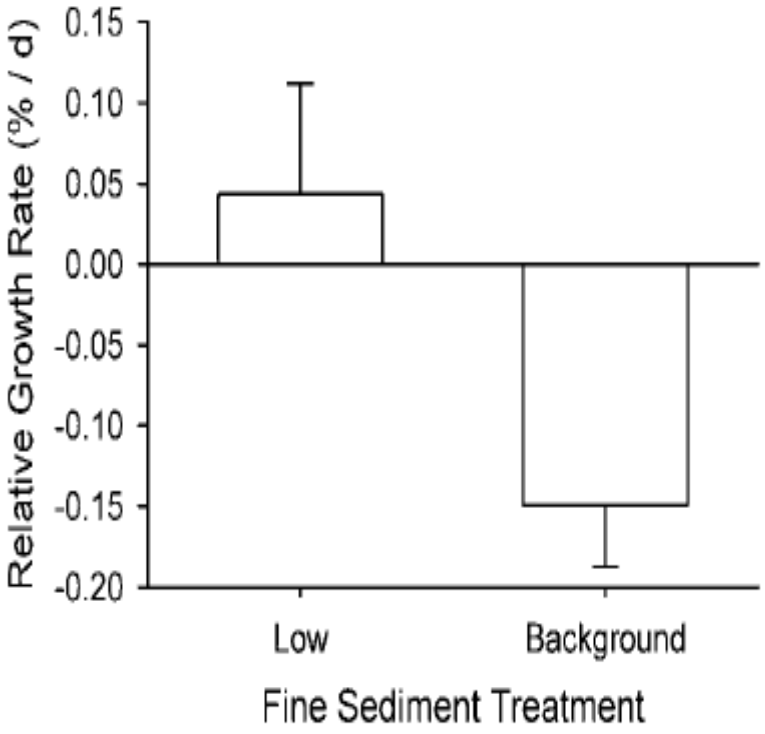
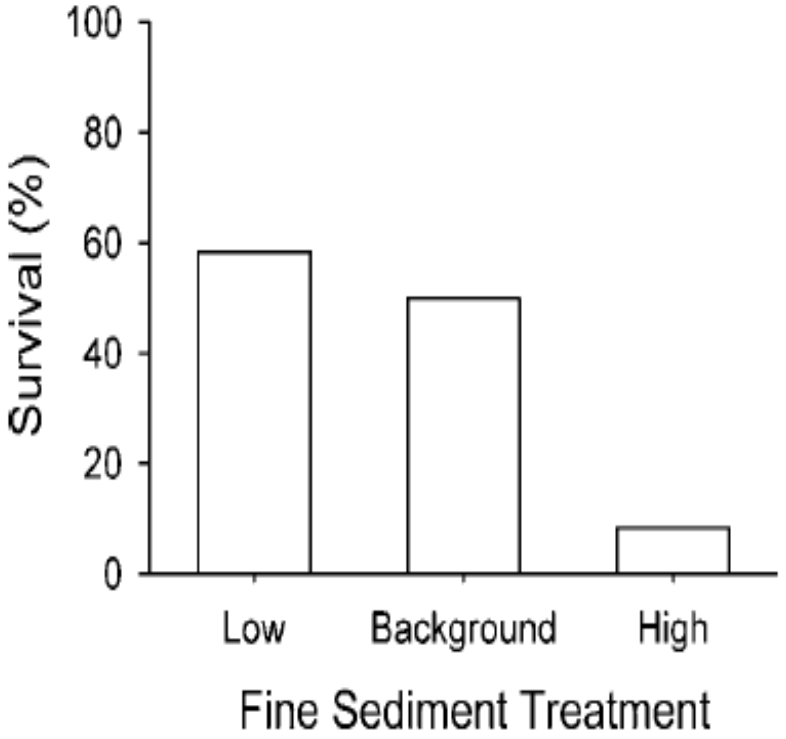
Harvey et al. (2009)





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Effects of deposited fine sediment on juvenile salmonid habitat.

- Take Home Message
  - “The linear relationship between deposited fine sediment and juvenile steelhead growth suggests that there is no threshold below which exacerbation of fine-sediment delivery and storage in gravel bedded rivers will be harmless, but also that any reduction could produce immediate benefits for salmonid restoration.” Suttle et al. (2004)

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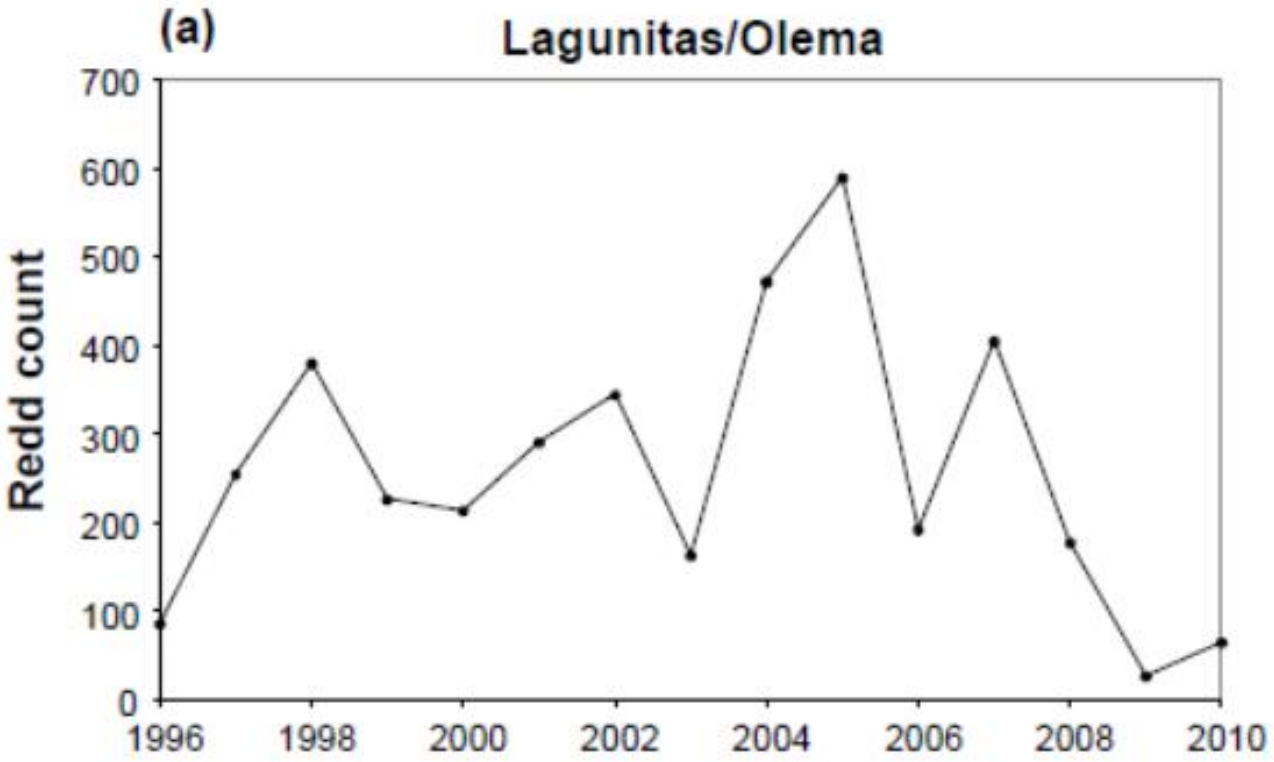
Current Situation



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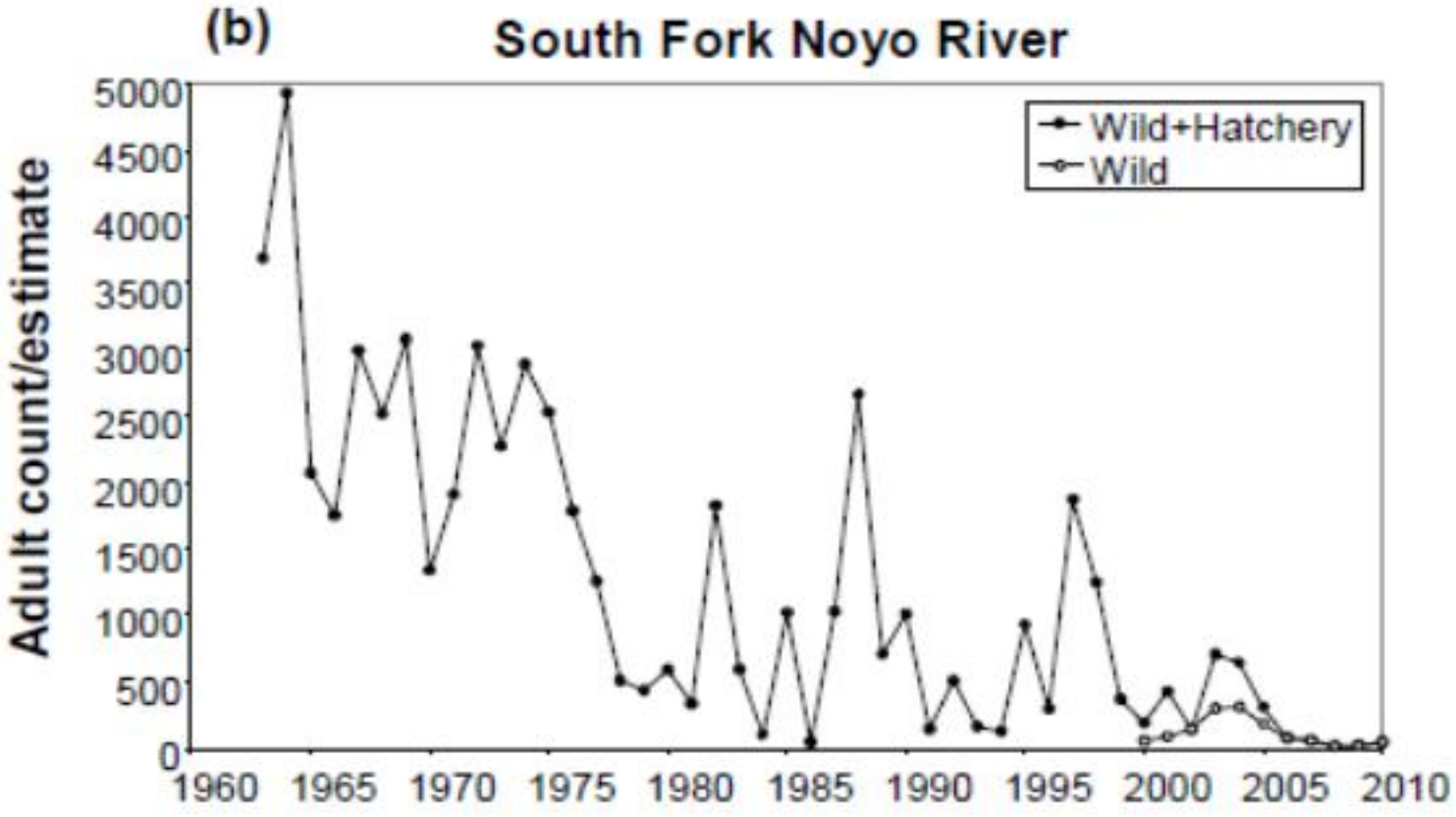

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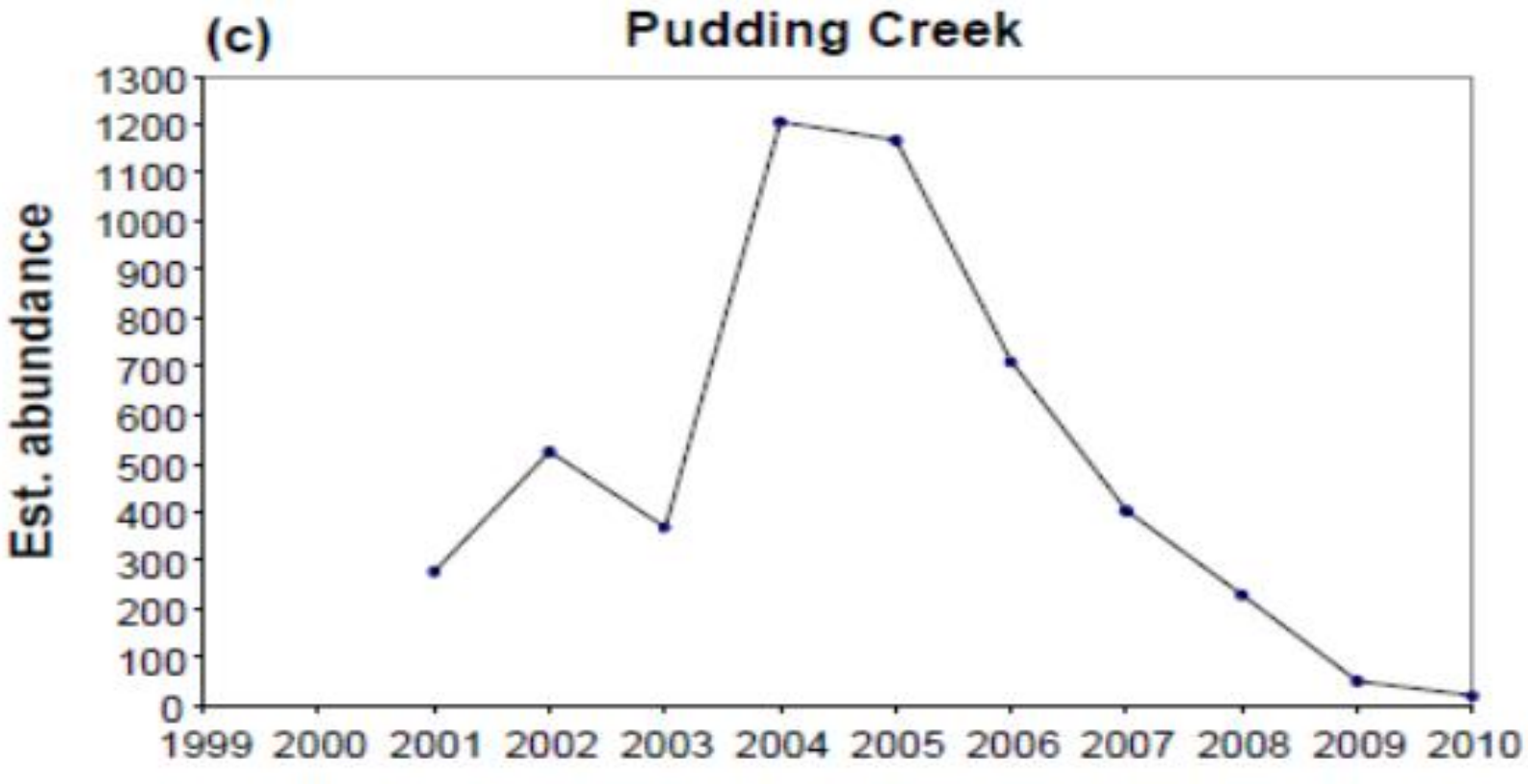

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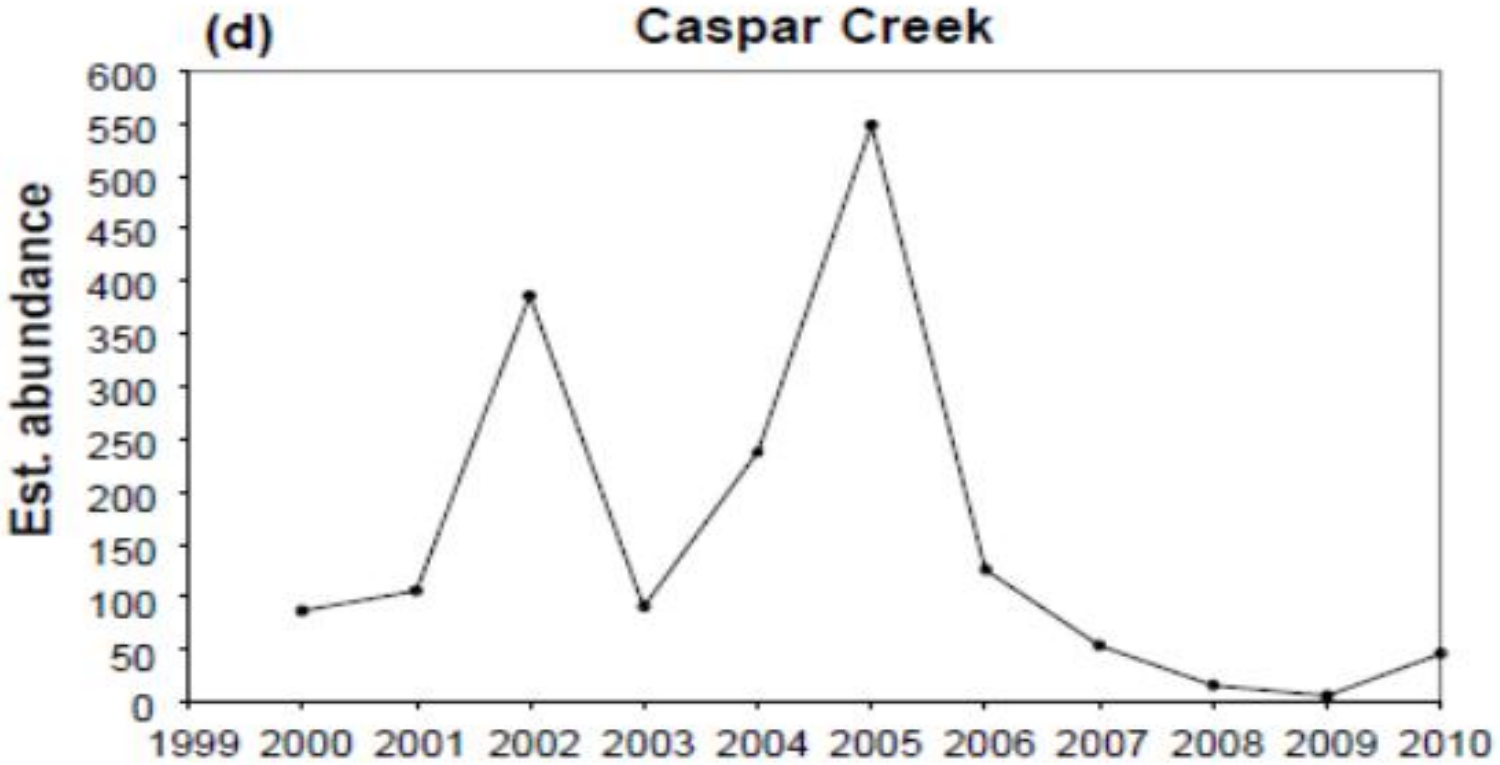

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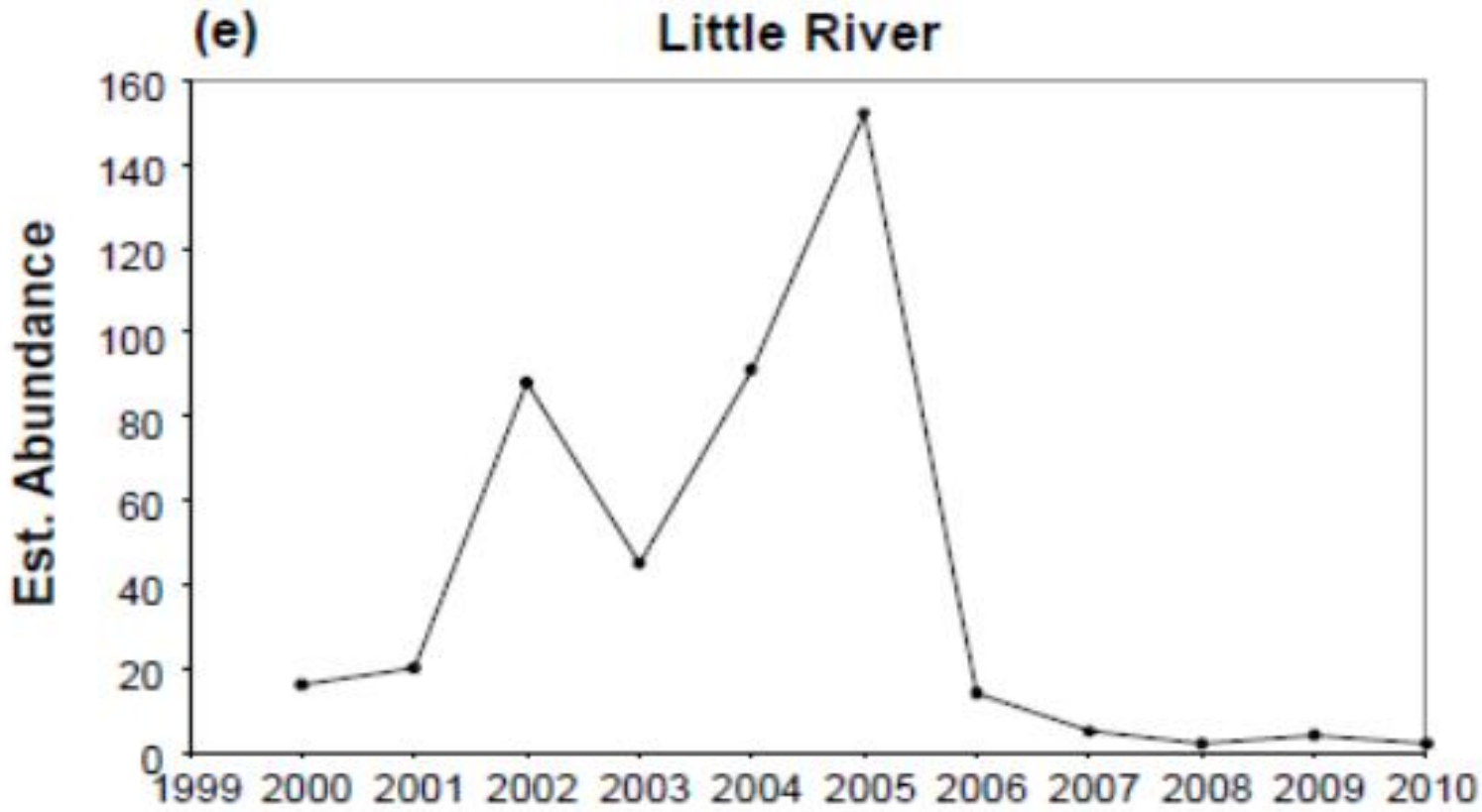

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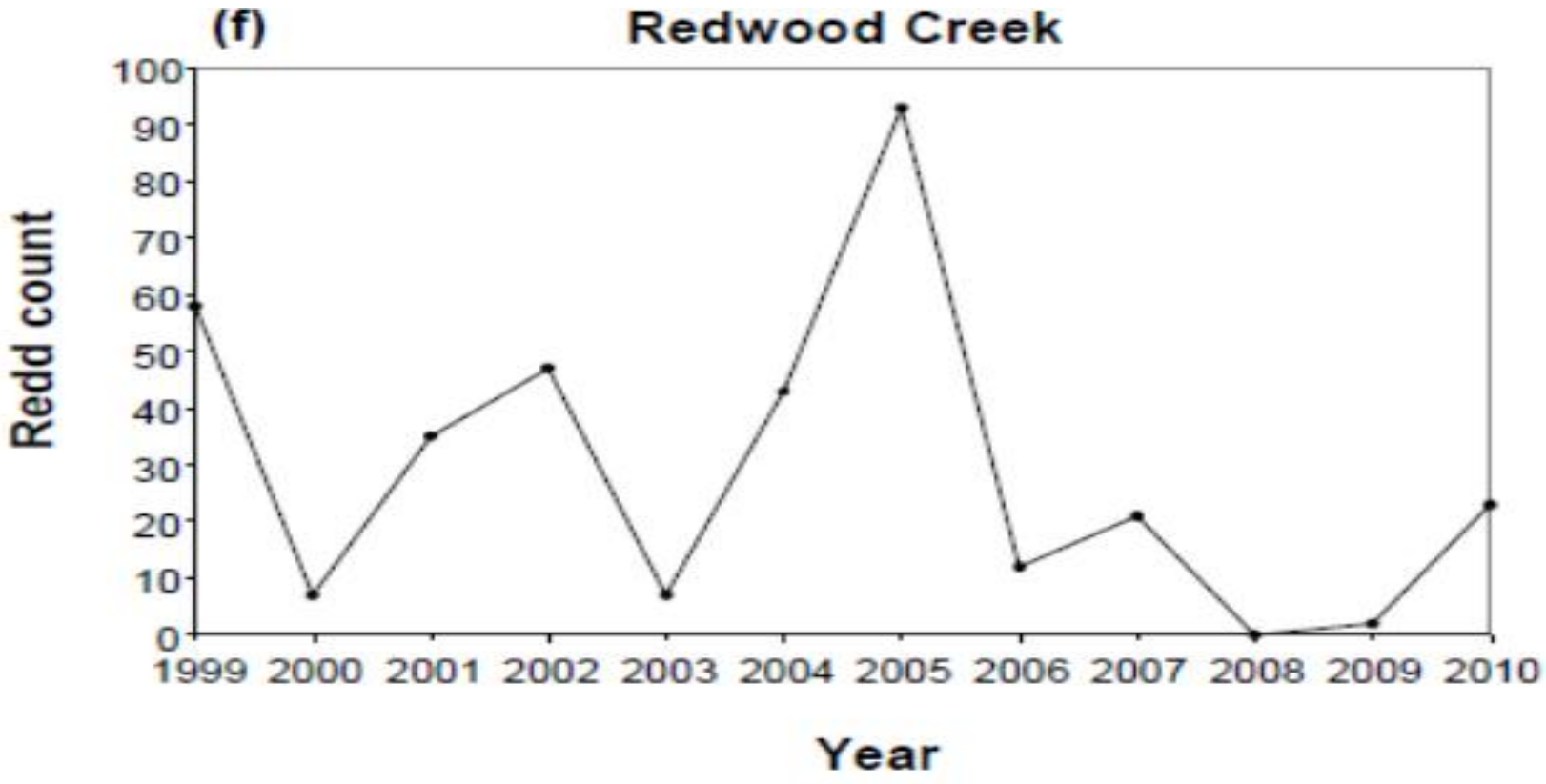

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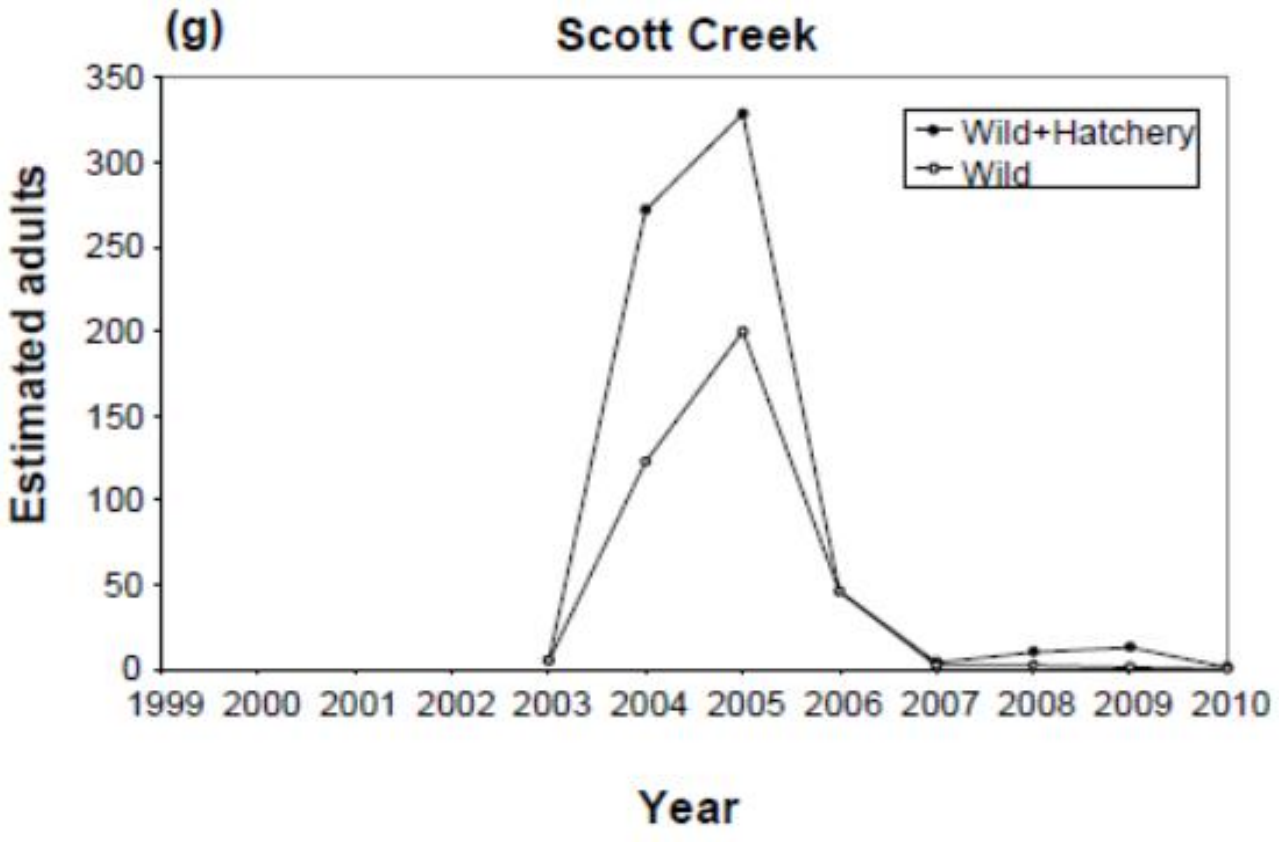

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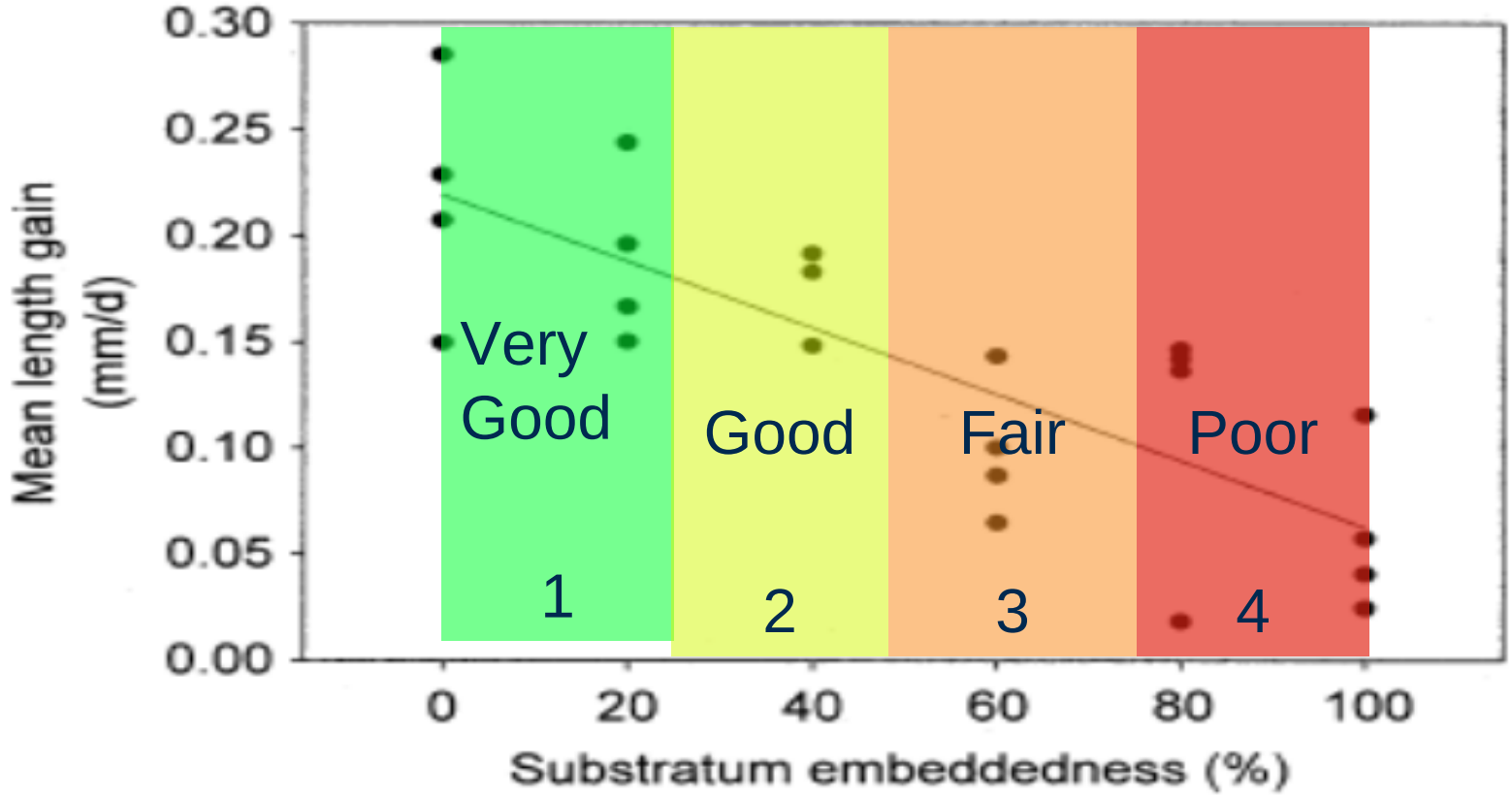
Existing Condition of Streams CDFG habitat data



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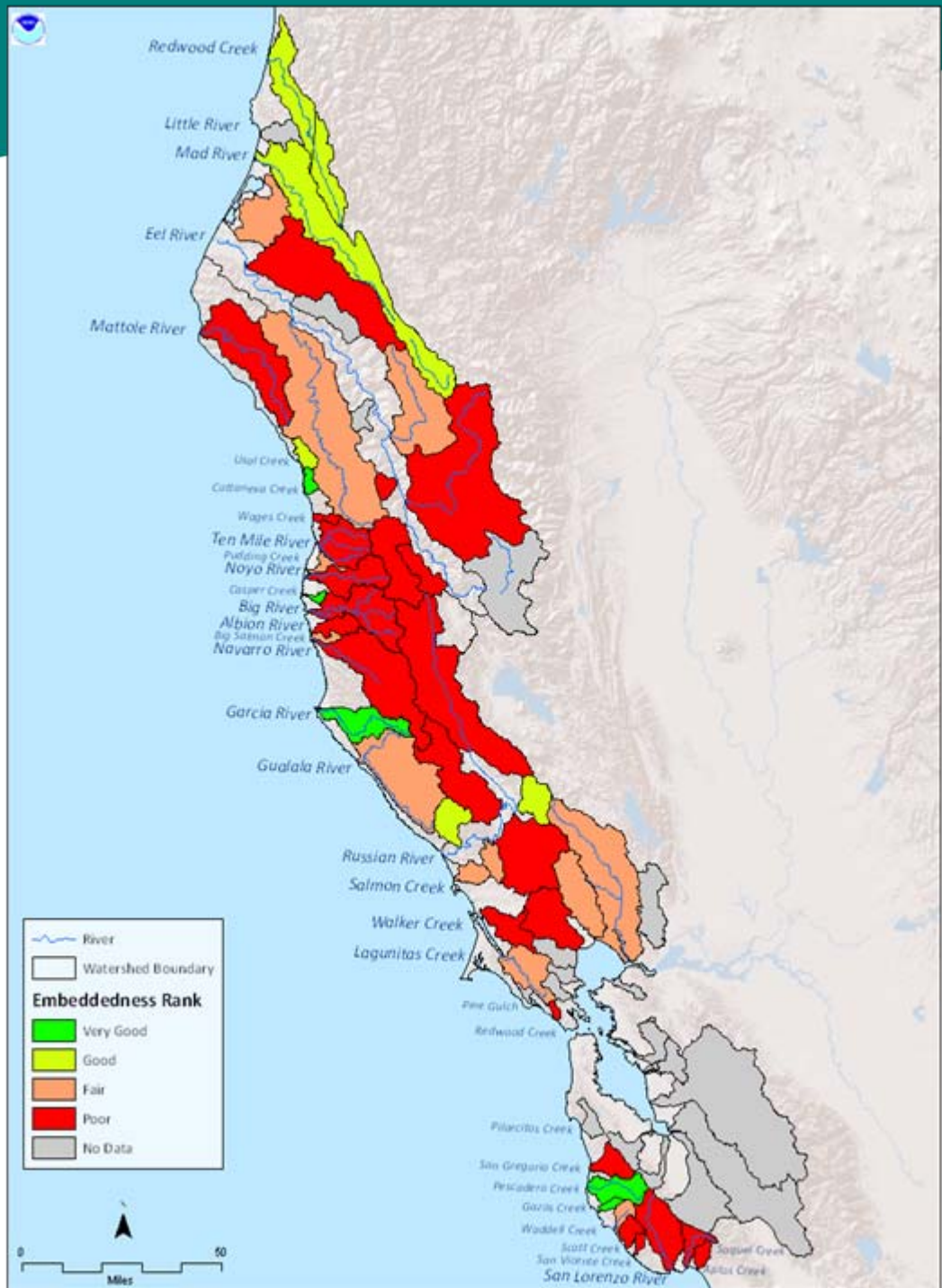
- 34% of the watersheds ranked good or very good.
- 48% of the watersheds ranked poor.



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Facts

- Fine sediment causes harm to salmonids when it is suspended and when it is deposited. Small increases in fine sediment significantly increases the likelihood of take in multiple life stages by:
  - Reduces growth and therefore decreases probability of ocean survival.
  - Suffocates eggs in redds
  - Increases stress
  - Increases mortality.
- The level of effect that suspended fine sediment has on salmonids depends on a complicated interaction between concentration and exposure.
- Anadromous salmonid populations are dangerously low.
- ASP watersheds are in poor condition
- The existing policy to prevent significant discharge is insufficient and ineffective in minimizing harm.

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Conclusions

- To reduce risk and uncertainty to listed salmonids any rule needs to meet these objectives:
  - High standard of erosion control
  - Clear and enforceable
  - Specifically regulate activities that cause discharge rather than regulate the quantity of discharge.

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